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Achieving Carbon Neutrality in California & 2022 Scoping Plan

Public Workshop

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Outline

- **Achieving Carbon Neutrality in California**
  - Study purpose and background
  - Scenarios
  - Key findings
  - Next steps
- **2022 CARB Scoping Plan**
  - Introduction (E3)
  - Public Health Analysis (UC Irvine)
  - Economic Analysis & Climate Impacts (Rhodium Group)

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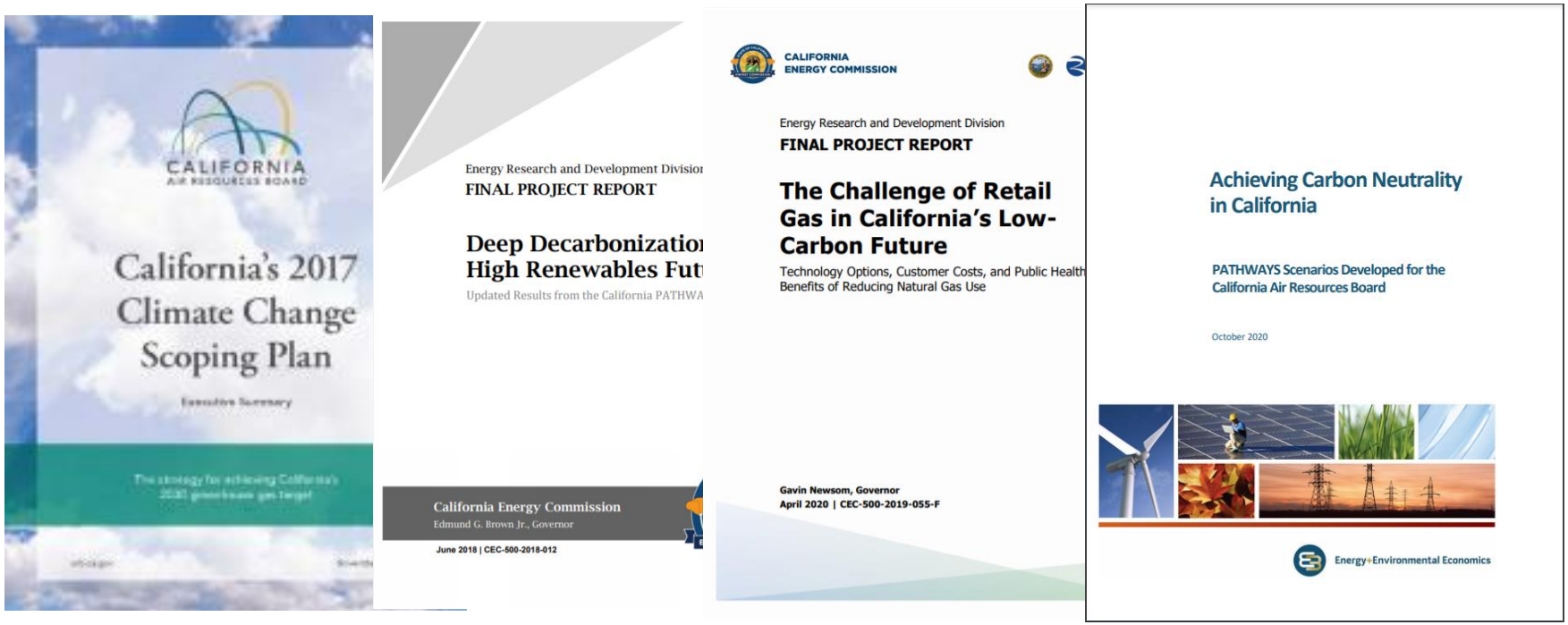
Achieving Carbon Neutrality in California

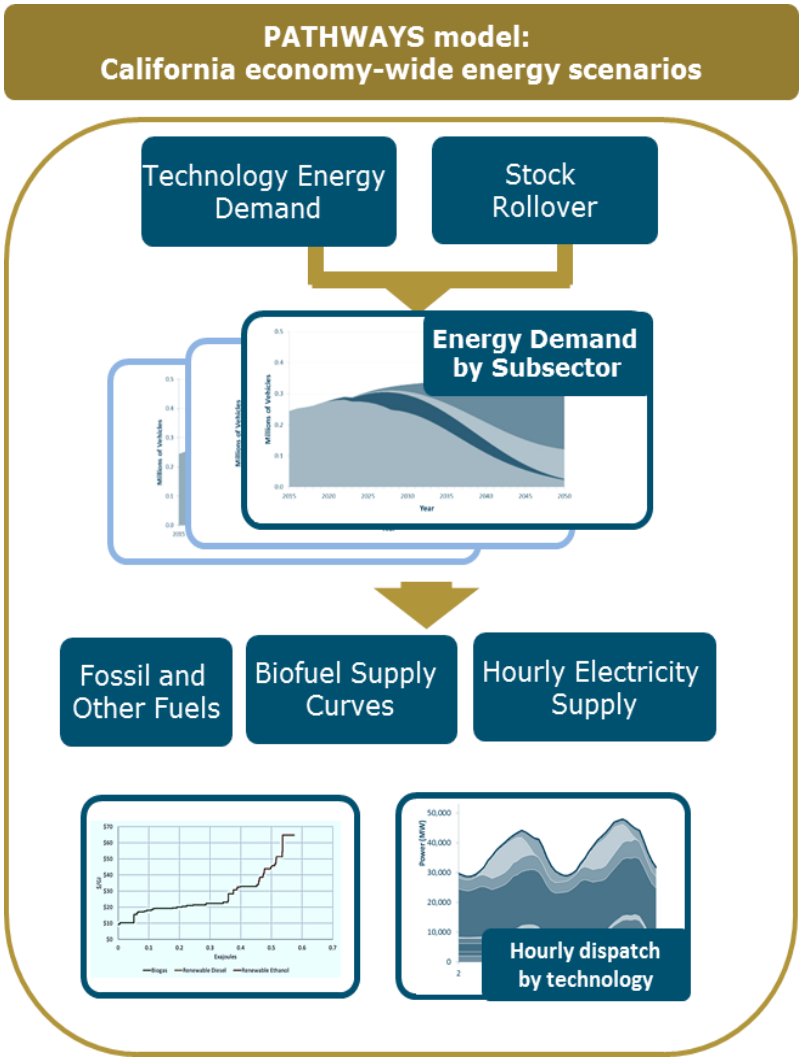
E3 Carbon Neutrality study published in Oct. 2020

- "Achieving Carbon Neutrality in California" study built on a literature review of deep decarbonization studies in the U.S. and Europe, and prior E3 research into decarbonization strategies in California, using the PATHWAYS model



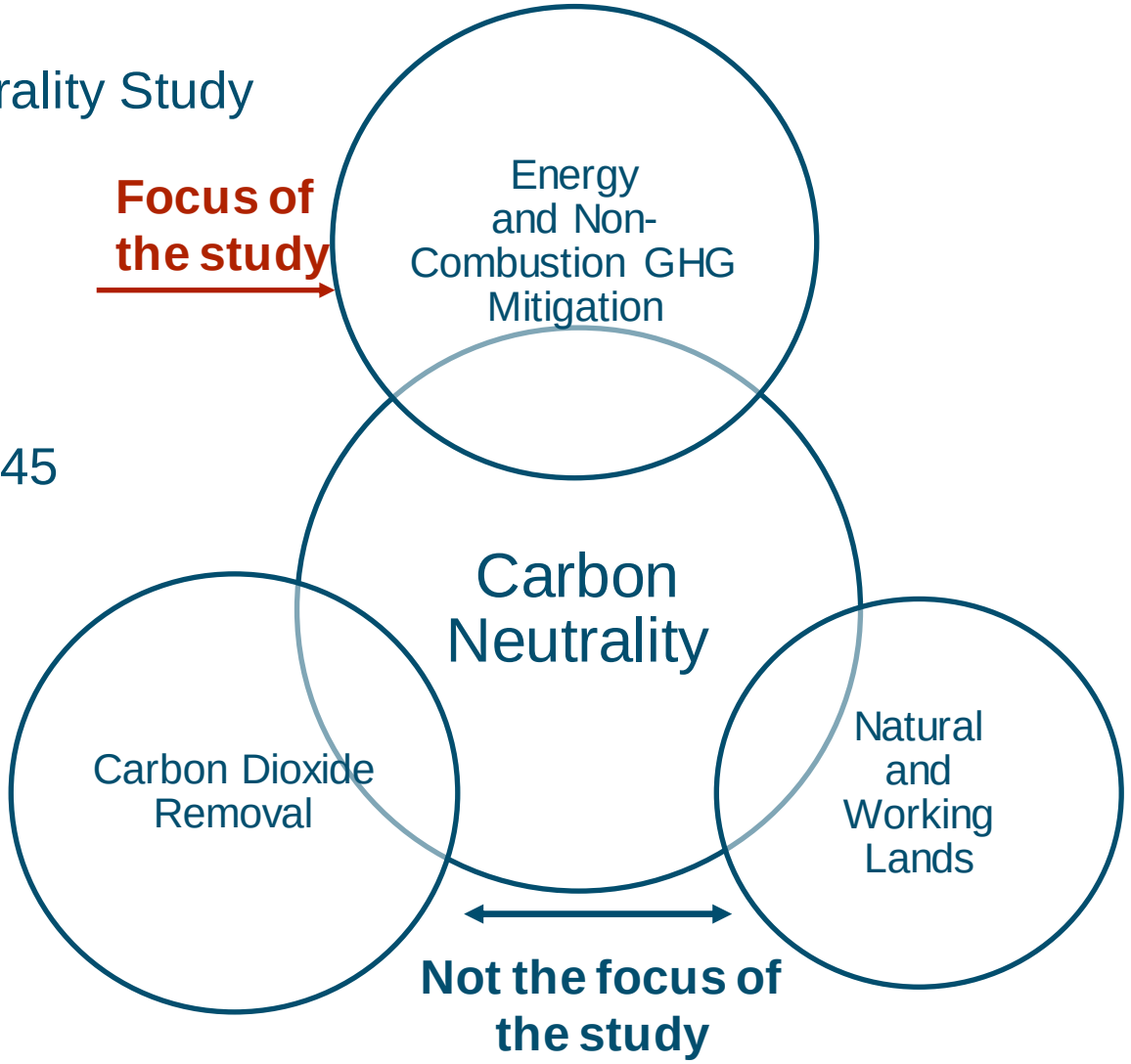
About the PATHWAYS model

- Covers California, economy-wide energy consumption and non-energy GHG emissions based on the CARB AB 32 Annual GHG Inventory
- Stock-roll over treatment of building equipment and vehicles in transportation provides realistic timeframes for technology adoption
- Biofuels, hydrogen, synthetic fuels, electricity sector representations reflect potential abatement opportunities from energy supply options



Carbon Neutrality Study Purpose

- Oct 2020 Carbon Neutrality Study examined potential **energy system and technology transformations** to achieve carbon neutrality by 2045 consistent with Executive Order B-55-18



Scenario Descriptions

+ "High Carbon Dioxide Removal (CDR)" scenario

- Broad range of deep decarbonization strategies, similar to E3's prior "high electrification" scenario, including energy efficiency, electrification, low-carbon fuels, zero-carbon electricity, and reductions in non-energy GHG emissions. *Highest reliance on CDR of all three scenarios.*

+ "Zero-Carbon Energy" scenario

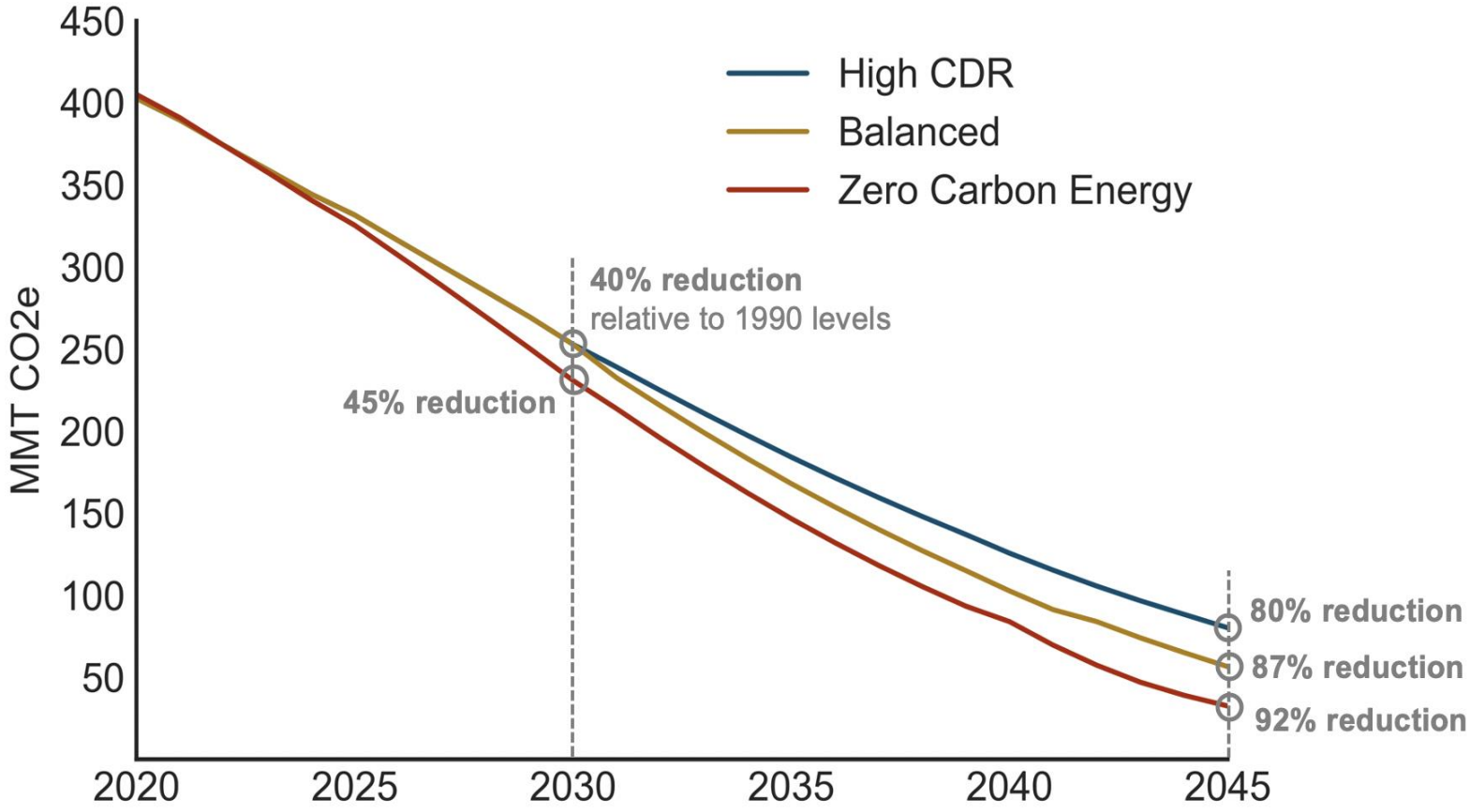
- Similar set of decarbonization strategies as the High CDR scenario but electrification is deployed *earlier* and *more completely*. Emerging emission reduction technologies, including synthetic natural gas in the gas pipeline, electric aviation, and fuel-cell trains in off-road transportation *eliminate all fossil fuel emissions by 2045*.

+ "Balanced" scenario

- Less reliance on CDR compared to the High CDR scenario; slower electrification and less reliance on emerging emission reductions technologies included in the Zero-Carbon Energy scenario, i.e. less electric aviation and hydrogen fuel-cell trains. *Intermediate direct GHG reductions between other two scenarios.*

Three Scenarios

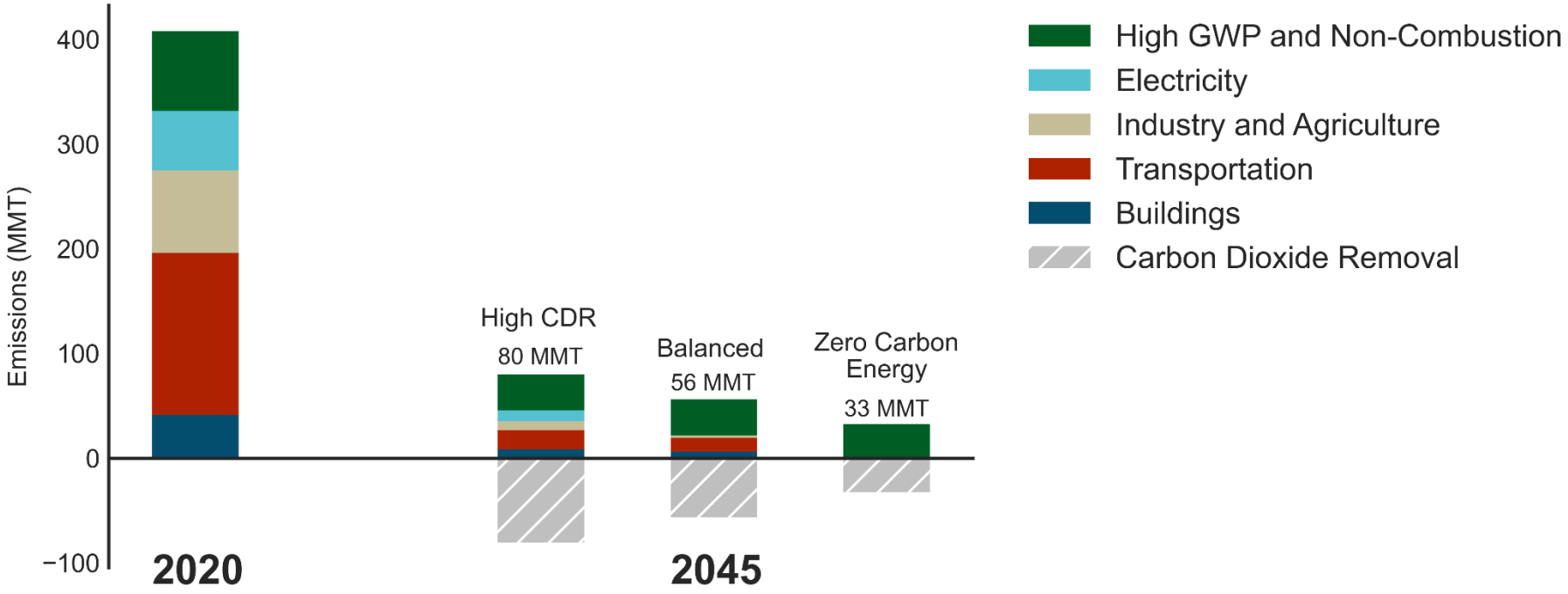
- Scenarios examined 80% to 92% reductions in direct emissions (energy and non-combustion GHGs) by 2045, using a "high electrification" scenario as the starting point for each



GHG Emissions: Scenario Comparison

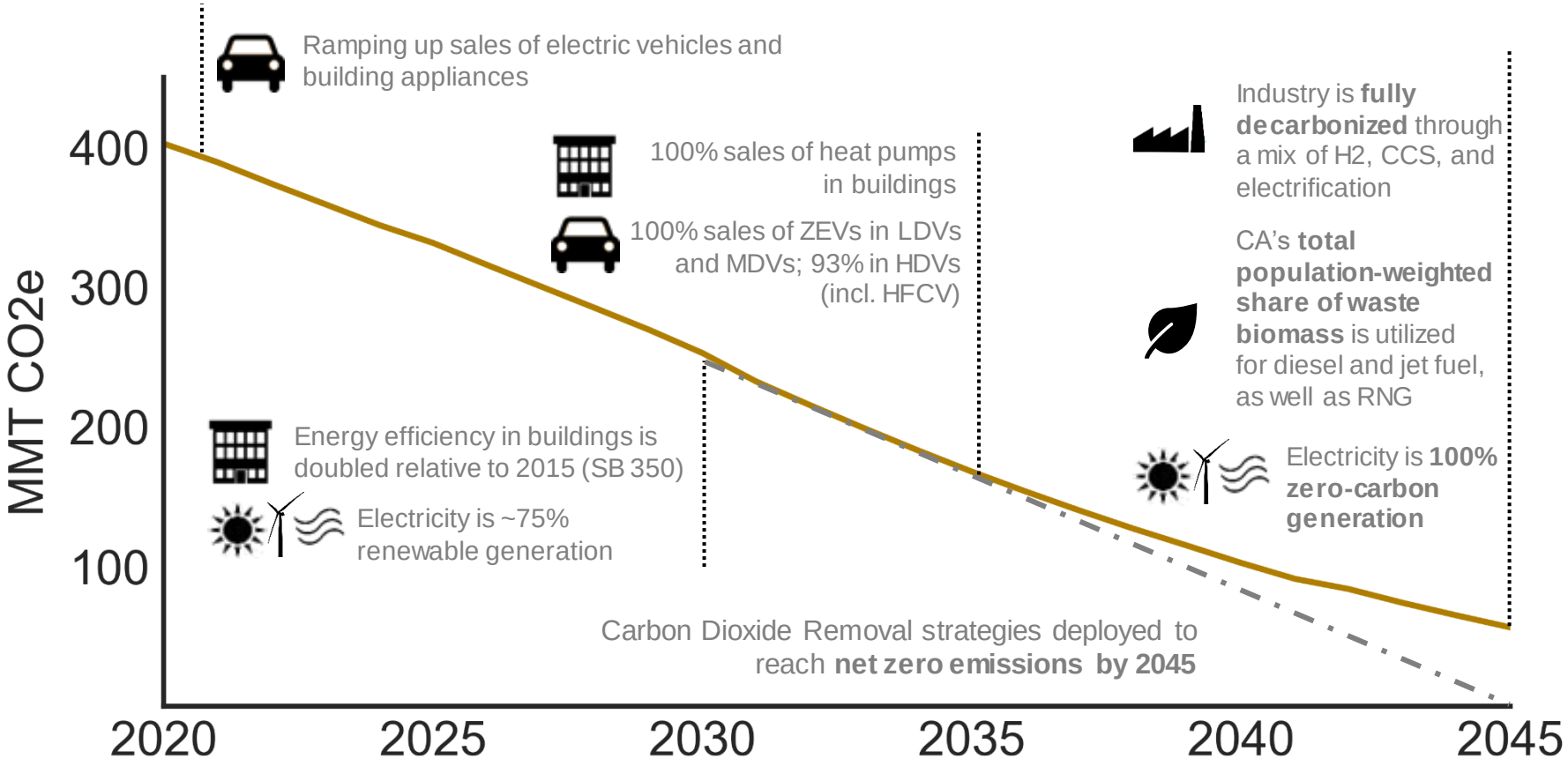
- **Largest source of remaining GHG emissions in all scenarios is from high global warming potential gases (GWP), e.g. fluorinated refrigerant gases and non-combustion emissions, e.g. fugitive methane from agriculture**

AB 32 emissions: today, and in 2045 across the three scenarios



Balanced Scenario: Key Assumptions

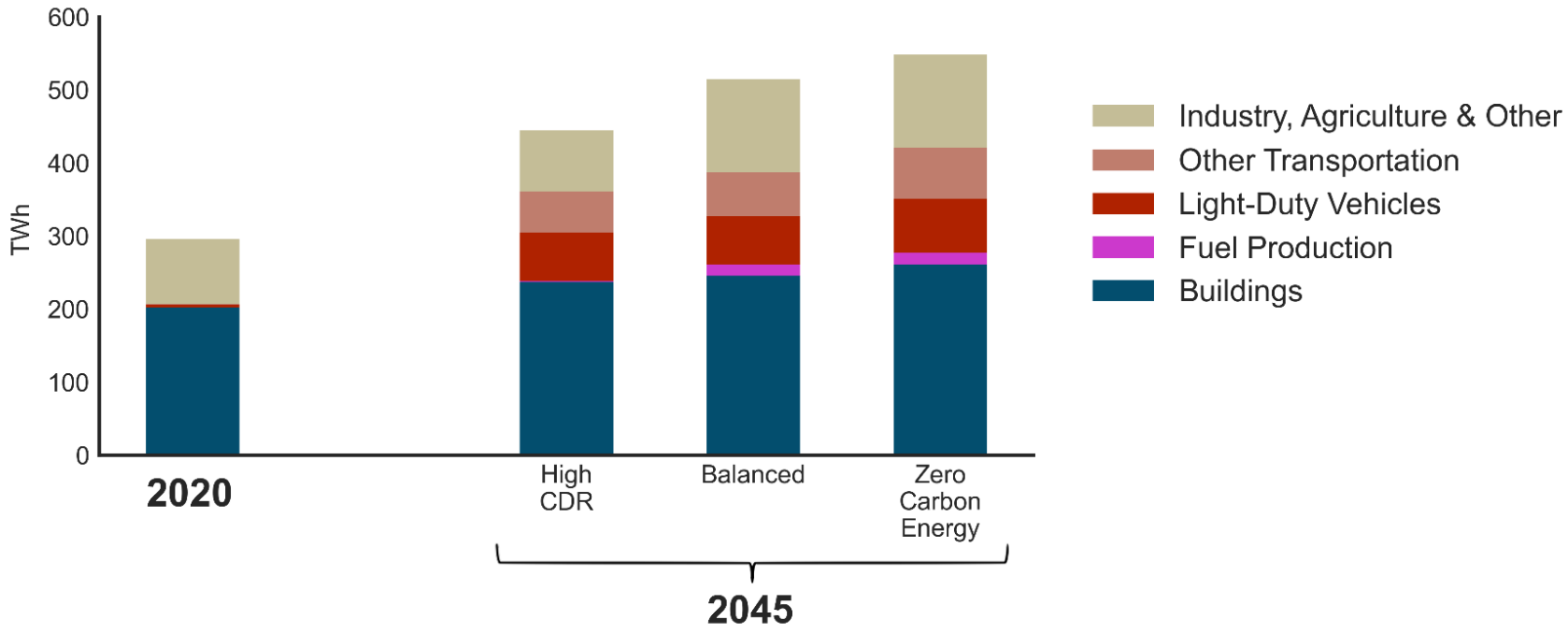
- **The "Balanced" scenario includes widespread efficiency and electrification paired with zero-carbon electricity, as well as zero-carbon fuels for hard-to-decarbonize sectors**



Electric Loads: Scenario Comparison

- Electric loads increase by 50-90% relative to today by 2045
- Loads for direct air capture (up to ~50-100 TWh) and hydrogen production to serve industry (~90 TWh in Balanced and ZCE scenarios) are assumed to be provided by off-grid renewables, and are not included in this graphic

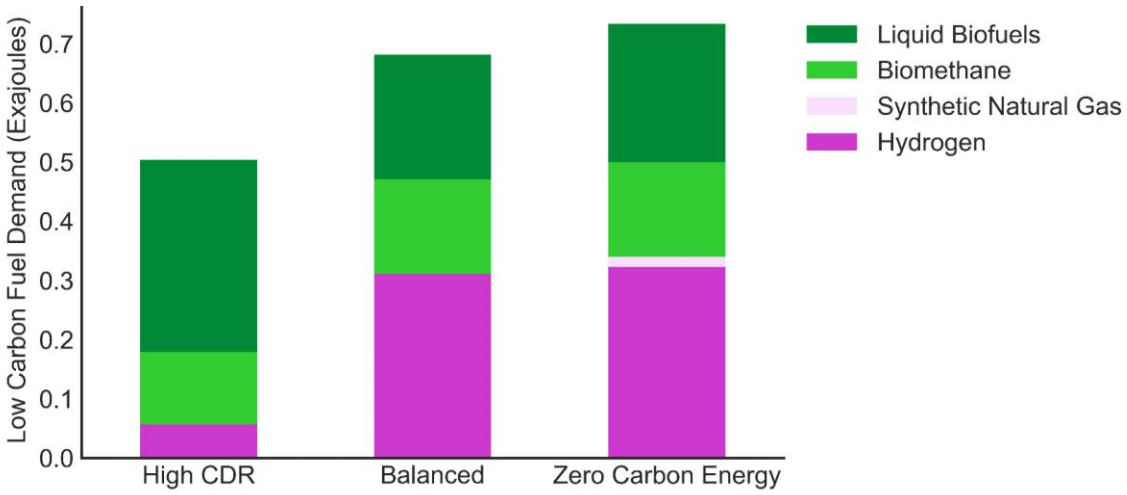
Electric loads by category: today, and in 2045 across scenarios



Low-Carbon Fuels: Scenario Comparison

- All scenarios assume similar total quantity of waste & residues biomass for biofuels, based on CA's population-weighted share of waste biomass
- All scenarios include hydrogen, Balanced and Zero Carbon Energy scenarios assume widespread use of hydrogen in HDV trucks & industry

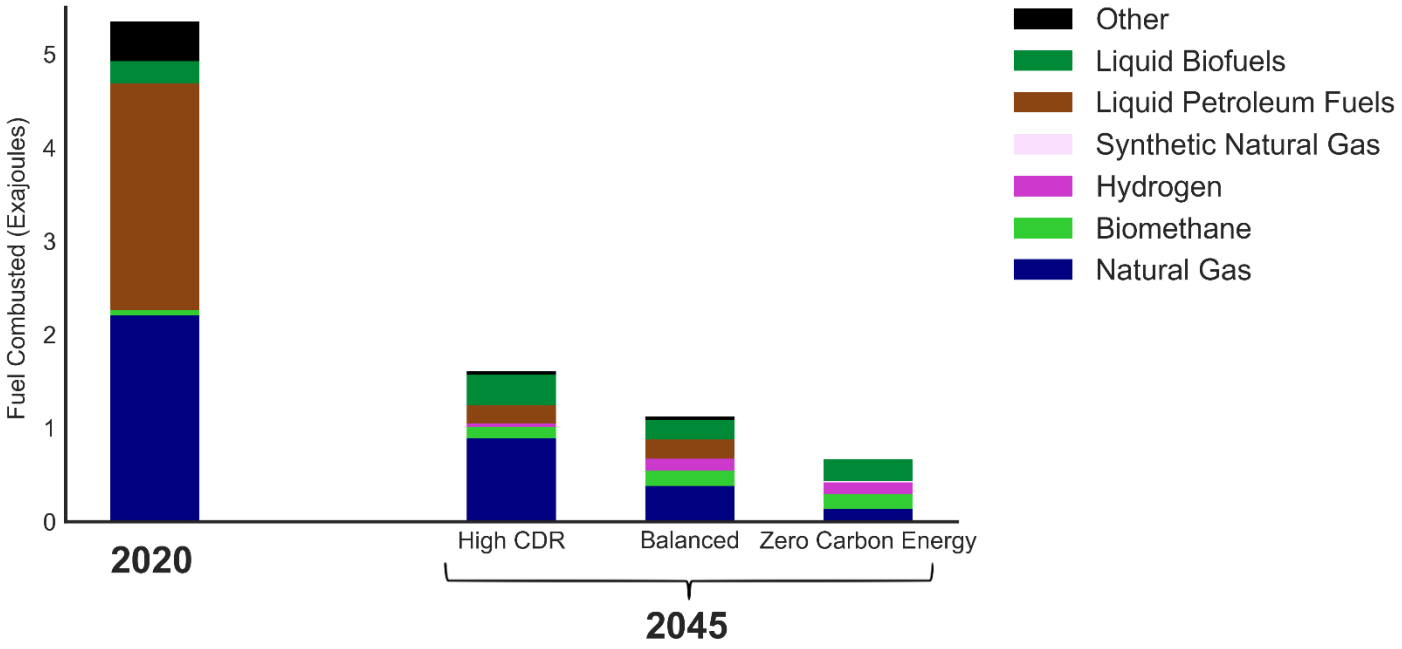
Low Carbon Fuel Demand by Scenario in 2045



Fuel Combustion: Scenario Comparison

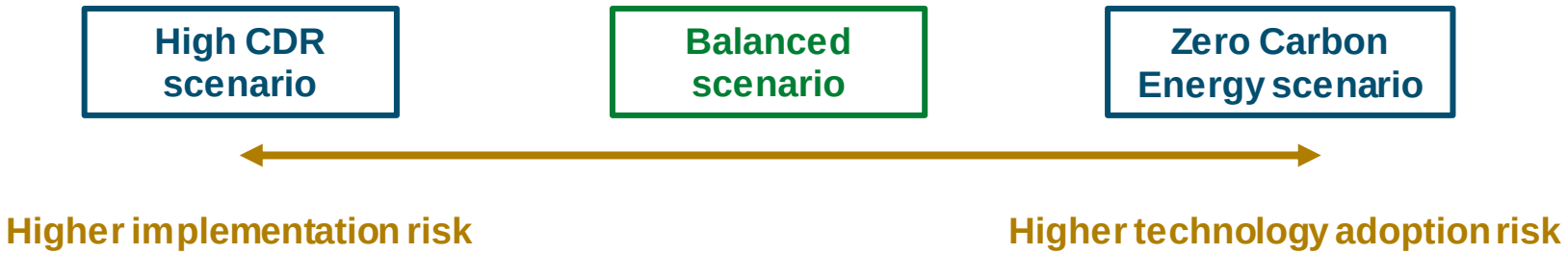
- **All scenarios include a significant reduction in fuel combustion relative to today, implying potential co-benefits for air quality and human health could be significant**
- **This study did not perform a detailed air quality analysis, but rather used total statewide fuel combustion as a proxy for potential human health impacts**
  - High CDR scenario has the highest relative risk for air quality and human health (although air quality would be significantly improved relative to today), while Zero Carbon Energy is the lowest risk. Fossil fuels in the Zero Carbon Energy scenario are associated with Carbon Capture and Sequestration.

Total statewide fuel combustion: today, and in 2045 across scenarios



Technology Adoption & Implementation Risk: Scenario Comparison

- **All scenarios involve risk trade-offs in the categories of technology adoption risk and implementation risk**
  - Technology adoption risk includes the risk that consumers will be able to feasibly transition to buying electric technologies by a certain timeline
  - Implementation risk includes the risk that certain technologies will be commercialized and cost-effective by 2045, such as hydrogen and biofuel production
- **The balanced scenario represents the lowest risk scenario in both of these categories, by minimizing reliance on non-commercialized technologies such as CDR, while also minimizing the technology adoption risk of rapidly transitioning to all-electric technologies**



Key findings

- **Least-regrets strategies** for getting to carbon neutral include:
  - **Energy efficiency in buildings, industry, and agriculture**
  - **Widespread transportation and building electrification**
  - **Zero-carbon electricity**
  - **Investment in zero-carbon fuel options for hard-to-decarbonize sectors where electrification is not practical**
  - **Pursuing reductions in non-combustion emissions**
  - **Investment and research into carbon dioxide removal (CDR) technologies**

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2022 Scoping Plan

Scoping Plan Analytical Support: Consultant Team

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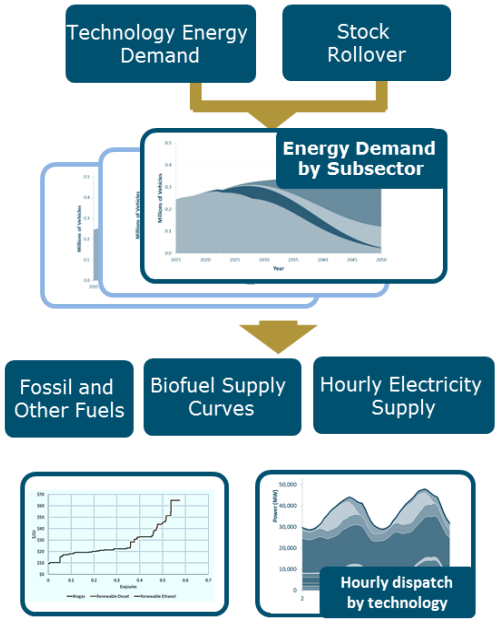
Advanced Power & Energy Program, University of California · Irvine

Rhodium Group

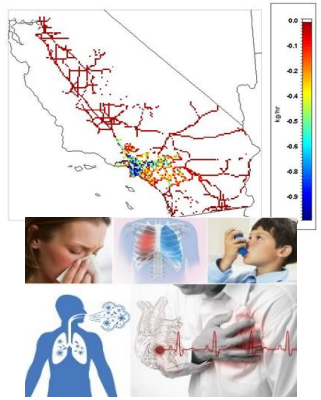
California economy-wide scenarios developed in collaboration with CARB

PATHWAYS model: California economy-wide energy and greenhouse gas scenarios (E3 lead & prime contractor for overall team)



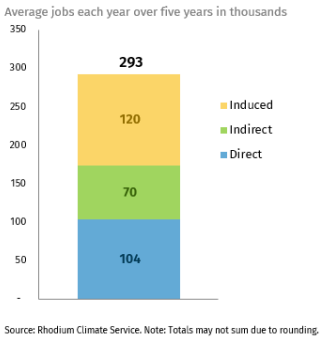
Air Quality and Health Impacts

SMOKE + CMAQ air quality models + **BenMAP model** for health impacts



Economic Analysis

IMPLAN macroeconomic modeling



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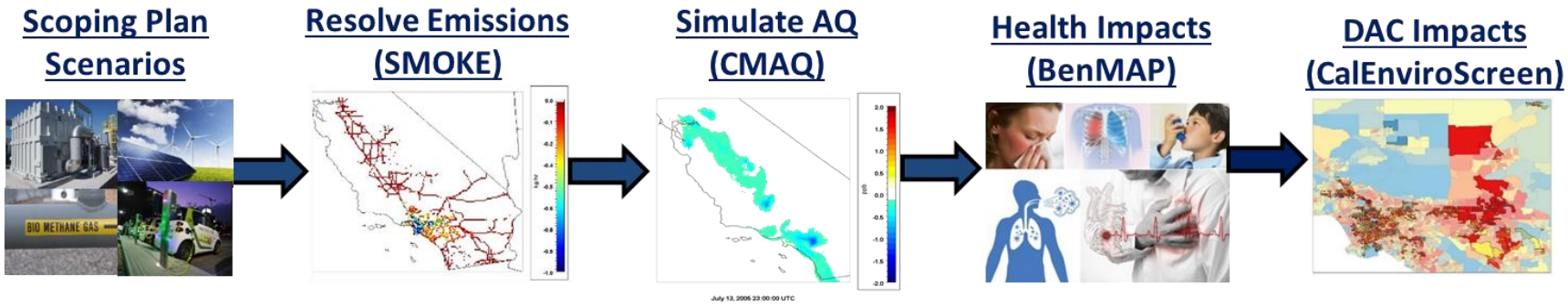
UCI Public Health Analysis

Public Health Benefits

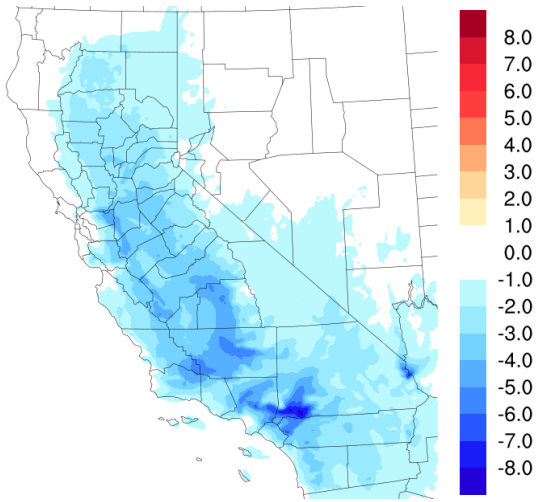
- **Comprehensive evaluation of the statewide air quality and public health benefits that accrue from the carbon neutral strategies within scenarios**
  - Quantify avoided societal costs from improvements in outdoor air pollution
  - Identify scenarios of carbon neutrality that maximize air quality co-benefits
  - Provide insight into health savings within disadvantaged communities



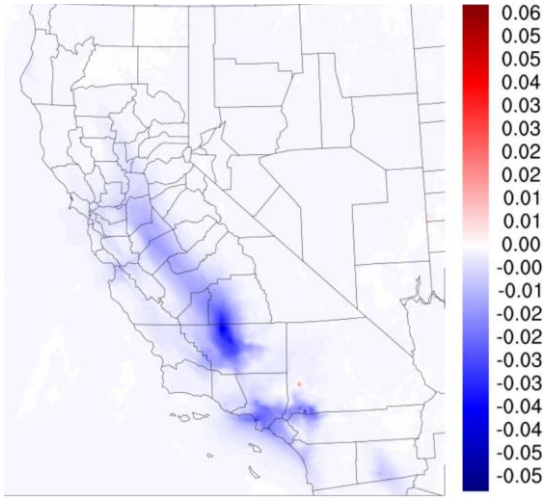
Community Multi-scale Air Quality Model (CMAQ)

- Simulation of atmospheric chemistry and transport required to understand impacts on primary and secondary pollutants concentrations
- Model performance verified with observational data[1]

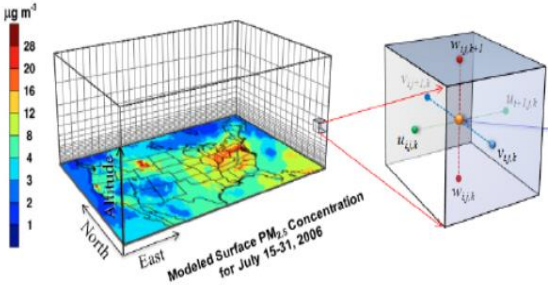
Δ Summer MD8H (ppb)



Δ Annual $PM_{2.5}$ (ug/m³)



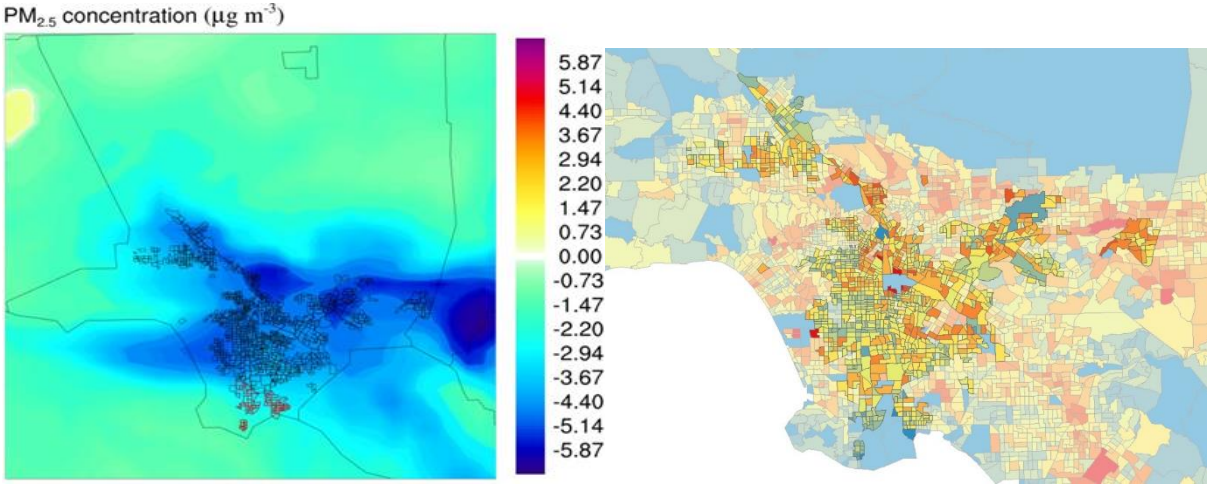
	Model or Data Source
Emissions Processing	SMOKE version 4.0
Air Quality Model	CMAQ version 5.3
Chemical Mechanism	SAPRC-07
Biogenic Emissions	MEGAN v2.1
Meteorological Files	WRF-ARW
Boundary Conditions	MOZART-4



1:Zhu, Shupeng, Jeremy R. Horne, Michael Mac Kinnon, G. S. Samuelsen, and Donald Dabdub. "Comprehensively assessing the drivers of future air quality in California." Environment international 125 (2019): 386-398.

Disadvantaged Communities (DAC)

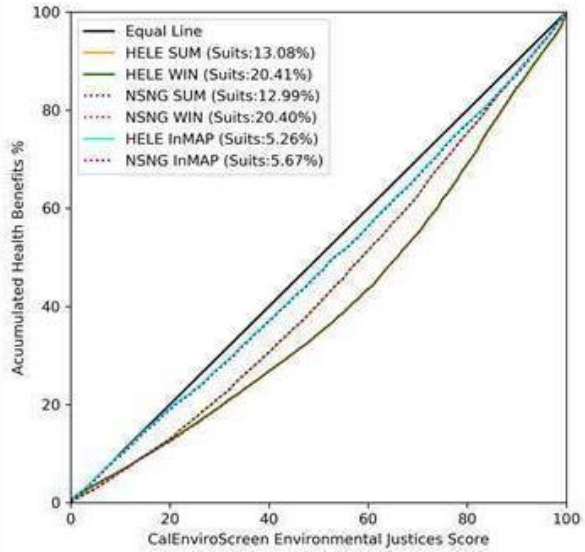
- **Quantify and assess health benefits in DAC to provide insight into environmental justice implications**
  - Identification of highly impacted or prioritized DAC
  - Ratio of public health benefits within DAC
  - Consider other economic metrics, e.g., Lorenz curves



Avoided Incidence of Mortality from $PM_{2.5}$ Exposure

Total CA: 2651

POLA DAC: 587



Distribution of health benefits across DAC

Rhodium Group

Economic Analysis and Climate Impacts

California's 2022 Climate Change Scoping Plan

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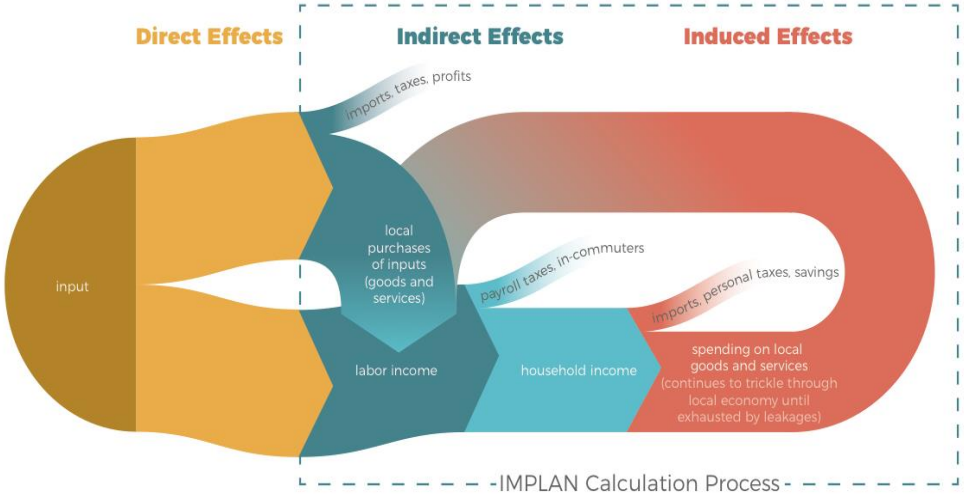
Rhodium Analytical Work Streams

- Job and Economic Analysis
  - Rhodium Group will work in coordination with E3, UC Irvine, and CARB to estimate the macroeconomic impact of Scoping Plan scenarios.
  - Rhodium will use IMPLAN to analyze the economic impact in 2045 of changes in expenditures resulting from policies and programs California may implement to achieve carbon neutrality.
  - Rhodium will provide an estimation of macroeconomic impacts at the state and county level and provide an analysis of the distribution of economic impacts for California communities that are disproportionately burdened by pollution as identified using CalEnviroScreen 3.0.
- Estimating Climate Impacts
  - Rhodium will quantify the global benefits of California's GHG reductions in both monetized and real-world impacts, using the Climate Impact Lab's updated Social Cost of Carbon (SCC) estimates.
  - For each county in California, Rhodium will utilize the Climate Impact Lab's pioneering, hyper-local evidence-based research to identify the climate damages for each county in California in 2045.

Macroeconomic Impacts will be estimated using IMPLAN

IMPLAN Economic Impact Study Flow



Source: IMPLAN

Rhodium will model changes in spending across the California economy that result from the Scoping Plan scenarios

Rhodium will estimate the impact of California's policies on the California economy, California businesses, and Californians in 2045

Rhodium will use the total costs and savings generated in CA PATHWAYS as inputs in IMPLAN representing expenditure changes by businesses and households

Rhodium will also use health impact data from UCI to estimate the change in health expenditures that result from changes in air pollution from the modeled climate policies

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Thank You